RESEARCH ARTICLE JSLS

Robo-Lap Approach Optimizes Intraoperative Outcomes in Robotic Left and Right Hepatectomy

Francesca Ratti, MD, Rebecca Marino, MD, Sara Ingallinella, MD, Lucrezia Clocchiatti, MD, Diletta Corallino, MD, Marco Catena, MD, PhD, Luca Aldrighetti, MD, PhD

ABSTRACT

Background: The aim of the present study is to evaluate the possible advantages of the Robo-Lap (parenchymal transection by laparoscopic ultrasonic dissector and robotic bipolar forceps and scissors) compared with pure robotic technique (parenchymal transection by use of robotic bipolar forceps and scissors) in major anatomical liver resections with specific focus on intraoperative outcomes.

Methods: Major liver resections performed by robotic approach between February 1, 2021 and March 31, 2023 were stratified into two groups according to the approach used to address the phase of liver transection; Pure Robotic Group (n = 21) versus Robo-Lap Group (n = 48). The two groups were compared in terms of intra- and postoperative outcomes and in terms of rate of achievement of intraoperative textbook outcomes.

Results: Conversion rate was similar between the two groups while incidence of adverse intraoperative events (according to Satava classification) was higher in the Pure Robotic compared with the Robo-Lap group (85.7% vs 39.6%, $p < 0.001$). Time to perform parenchymal transection was significantly shorter in the Robo-Lap group (180 min) compared with the Pure Robotic Group (240 min), $p = 0.003$. Intraoperative textbook outcomes were achieved in a lower proportion of patients in the Pure Robotic compared with the Robo-Lap group.

Conclusion: Outcomes of the present study suggest a favorable role of the Robo-Lap approach in robotic major resections as it allows an improvement of the intraoperative results, a greater probability of an uneventful conduction of the procedure, and therefore, better management of the operating room time.

Key Words: Liver Surgery, Robo-Lap, Robotic Surgery.

Hepatobiliary Surgery Division, San Raffaele Hospital, Milano, Italy. (all authors)

Vita-Salute San Raffaele University, Milano, Italy. (Drs. Ratti and Aldrighetti)

Acknowledgements: none.

Disclosure: none.

Conflict of interests: none.

Funding sources: none.

Informed consent: Dr. Francesca Ratti declares that written informed consent was obtained from the patient/s for publication of this study/report and any accompanying images.

Address correspondance to: Dr. Francesca Ratti, MD, Hepatobiliary Surgery Division, San Raffaele Hospital, Via Olgettina 60, 20132, Milano, Italy, Telephone: +39 02 26437811 / +39 0226437808 / +39 3482411961, Fax: +39 02 26437807, E-mail: ratti.francesca@hsr.it.

DOI: 10.4293/JSLS.2023.00025

INTRODUCTION

The minimally invasive approach has gained a main role in the setting of liver surgery due to well-documented perioperative advantages for the patient and to maintained oncological efficacy compared with the open approach.[1–4] This evolution has been supported by the progressive technical and technological improvement that occurred over the course of the past 20 years.[5,6] Furthermore, the encouraging outcomes of minimally invasive liver Surgery (MILS) have constituted an incentive for technological investment to overcome technical difficulties initially described in this area. Today it is possible to perform procedures with a high degree of difficulty due to the availability of operating theaters equipped with advanced instrumentation and specifically designed to meet the needs and tasks of liver surgery.[7,8] However, the robotic approach has spread more slowly and with latency compared with laparoscopy.[9] The list of possible reasons for this delay includes the still irregular and low diffusion of the platform, the reduced availability of time slots dedicated to robotic liver surgery, and also the dissatisfaction of liver surgeons regarding the availability of instruments for precise and accurate parenchymal transection.

In a recent survey on the implementation of MILS, the most used transection technique in robotic liver surgery includes the combination of bipolar forceps (used in a Kellyclasia-like fashion, i.e. clamp-crushing) associated with monopolar scissors. The lack of an ultrasonic dissector is reported as the main concern for a large-scale implementation of robotic liver surgery.[9] To meet the need for thorough parenchymal dissection without renouncing to the advantages provided by the dexterity of the robotic technique, a hybrid technique (Robo-Lap approach) has been described.[10] It is based on a mixed transection through the laparoscopic ultrasonic dissector handled by the bed-side surgeon, associated with the action of robotic monopolar scissors, and bipolar forceps managed by the surgeon at the console. However, there are currently no studies comparing the pure robotic technique with the Robo-Lap technique in terms of short-term intraoperative and postoperative outcomes.

The aim of the present study is therefore to evaluate, in a tertiary referral center with a high volume of minimally invasive activity, the possible advantages of the Robo-Lap compared with the pure robotic technique in major anatomical liver resections with specific focus on intraoperative outcomes (conversion, intraoperative complications, blood loss, possibility to perform a second liver resection within the same day). Secondary endpoint is the comparison between the two approaches in the rate of achievement of intraoperative textbook outcomes (TO).

MATERIALS AND METHODS

The program of robotic liver surgery was implemented February 1, 2021, and the existing background of minimally invasive laparoscopic liver resections included 1,543 cases (performed from 2005 on). From February 1, 2021 to March 31, 2023, 250 hepatic resections were performed by robotic approach, including 69 anatomical major hepatic resections (i.e., H5678 right hepatectomy and H234 left hepatectomy).[11] All major liver resections were performed after the 25th case of the overall series of robotic resections (i.e., having completed the learning curve in robotic liver surgery, as reported in **Figure 1**).[25] Major liver resections were stratified into two groups according to the approach used to address the phase of liver transection; Pure Robotic Group (n = 21) versus Robo-Lap Group (n = 48). The two groups are temporally consecutive (i.e., Pure robotic from July 2021 to January 2022 and Robo-Lap from February 2022 on) as the Robo-Lap technique was implemented later than the adoption of the pure robotic technique and since then was adopted as the standard modality for liver transection. The two groups were compared in terms of intra- and postoperative outcomes and in terms of rate of achievement of intraoperative TO.

Approval to perform this retrospective study was obtained from the Institutional Review Board of our institution and the requirement for consents from subjects was waived.

Assessed Variables

Data on pre-operative patient and disease characteristics were prospectively collected, as well as on intraoperative and histopathological findings and postoperative course of patients.

Specifically, data regarding the following issues were collected for the purposes of the present study: operating room time required for liver transection phases, conversion rate and reason for conversion, intraoperative and postoperative complications, postoperative hospitalization (length of stay before discharge), possibility to perform a second liver resection during the same day of the procedure included in the study, and rate of achievement of intraoperative TO.[13]

TO is a novel composite quality measure that encompasses multiple postoperative endpoints, representing the ideal "textbook" hospitalization for complex surgical procedures also in the setting of hepatobiliary surgery.[14]

Intraoperative TO were defined as follows: no conversion, no intraoperative blood transfusion, no need for hemostatic agents during or at the end of liver transection, R0 resection.

Any complication occurring during the intraoperative course of the procedure significantly affecting the course of surgery was recorded. More specifically, any intraoperative accident was recorded according to Satava classification of intraoperative events.[15] Postoperative complications during the hospitalization period were reviewed for 90 days after surgery and assessed according to the Clavien-Dindo classification of surgical complications.[16] Mortality was defined as any death during intraoperative or postoperative hospitalization or within 90 days after resection.

Surgical Technique

General Features for Both Approaches

For all resections, a laparoscopic 10-mm trocar was positioned in right pararectal position, along the umbilical line.[1,10] Four robotic trocars were positioned in a standardized configuration with one trocar in right flank, one along the mid-clavicular line, one along the midline and one in left hypochondrium and the robotic platform was docked to operating table coming from the head (Da Vinci X platform) or from the right side (Da Vinci Xi platform) of the patient, oriented in reverse-Trendelenburg position. A second laparoscopic access was positioned in right hypochondrium (between robotic arms 1 and 2

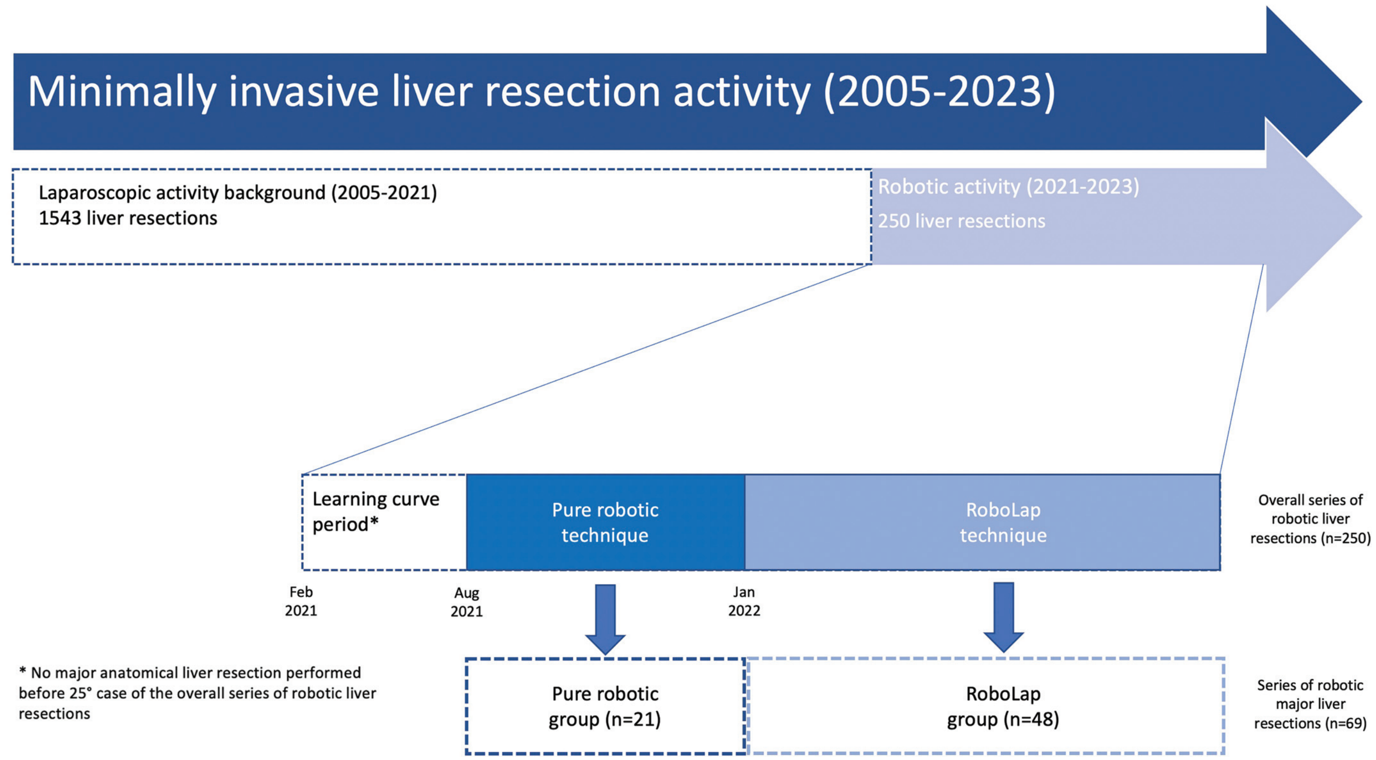


Figure 1. Study design.

or between 2 and 3) only after docking of robotic arms, to exclude conflicts among laparoscopic and robotic instruments and to improve ergonomics. In case of difficult or unsatisfactory control of the hemostasis during the parenchymal transection phase or at the end of resection, hemostatic agents (fibrin glue) were used on demand to optimize the temporary and the final hemostasis respectively.

Pure Robotic Approach

In this approach, the parenchymal transection technique involved the use of the branches of the bipolar forceps to perform a Kellyclasia-like dissection (clamp-crushing technique includes mechanical parenchymal demolition by crushing hepatocytes with Kelly forceps) of the liver parenchyma, aiming to split hepatocytes while preserving vascular (portal and hepatic veins) and biliary structures, then coagulated or closed between clips according to their caliber.

Robo-Lap Approach

Technical details regarding Robo-Lap approach have been described elsewhere.[10] Briefly, ultrasonic dissector was used for parenchymal transection by the surgeon at the table, dissecting the liver parenchyma while preserving vessels and biliary branches that were then coagulated or clipped according to their size. Dissection technique followed the same principles of ultrasonic mediated transection in laparoscopic surgery. The direction of the tip of the ultrasonic dissector was optimized to obtain an effective transection without being limited in its movement by robotic arms outside and robotic instruments inside the abdomen. Maintaining the principle of having the transection area in the middle of the visual field of both operators, it was possible to use the ultrasonic dissector and the robotic bipolar forceps and scissors for coagulation and cutting at the same time.

Statistical Methods

All variables were compared using the χ^2 or Fisher's exact test for categorical data, the Mann–Whitney U test for non-normally distributed continuous data, and Student's *t*-test for normally distributed continuous variables. All data are expressed as mean plus or minus the standard deviation or median and range. Significance was defined as $p < 0.05$. All analyses were performed using the statistical package SPSS 18.0 (SPSS, Chicago, IL, USA).

RESULTS

General Characteristics and Indications

Patients and disease characteristics of Pure Robotic and Robo-Lap groups are reported in **Table 1**. Groups did not show significant differences in terms of age, sex, biometrics, and presence of underlying liver impairment or cirrhosis.

Diagnosis distribution was similar between the two groups. Hepatocellular carcinoma was the most frequent diagnosis in the Pure Robotic Group (38.1%) while cholangiocarcinoma (either intrahepatic or perihilar) was the most frequent in the Robo-Lap Group (47.9%). A significantly higher number of patients in the Robo-Lap Group underwent interventional procedures before surgery: hepatic deprivation in 27.1% (versus 19% in the Pure Robotic group) and biliary drainage in 33.3% (versus 14.3% in the Pure Robotic group).

Mean lesion size was comparable between the groups (6.9 cm versus 6.5 cm respectively, $p = 0.248$), as well as lesion numerosity (specifically, 38.1% in the Pure Robotic and 25% in the Robo-Lap had multiple lesions). Distribution of procedures was similar: 11 patients in the Pure Robotic (52.4%) and 28 in the Robo-Lap group (58.3%) underwent right hepatectomy, while 8 (38.1%) and 12 (25%) respectively underwent left hepatectomy. Eight patients in the Pure Robotic and 27 in the Robo-Lap group received associated procedures during surgery; most frequently performed were lymphadenectomy (23.8% and 47.9% respectively) and biliary anastomosis (14.3% and 35.4% respectively), with no statistically significant difference.

Intraoperative Outcome Data (Primary Endpoint)

Minimally invasive procedures were successfully completed in 19 patients in the Pure Robotic and 43 patients in the Robo-Lap group, whereas the procedure was converted to laparotomy in 2 (9.5%) and 5 (10.4%) patients respectively (p not significant): reasons for conversion were bleeding (2 cases), concerns regarding oncological radicality (2 cases), need to perform portal vein resection (1 case), infiltration of the inferior vena cava (1 case). Incidence of grade I (respectively 57.1% and 20.8%) and grade II (respectively 23.8% and 14.6%) intraoperative events according to Satava classification were significantly higher in the Pure Robotic compared with the Robo-Lap group, resulting in a higher incidence of intraoperative events in the Pure Robotic compared with the Robo-Lap group (85.7% vs 39.6%, $p < 0.001$). The mean operative time comparable between the two groups, while time to perform parenchymal transection was significantly shorter in the Robo-Lap group (180 min) compared with the Pure Robotic Group (240 min), $p = 0.003$. In spite of a comparable intraoperative use of the Pringle maneuver and of a statistically comparable blood loss (450 mL vs 350 mL in the Pure Robotic and Robo-Lap groups respectively) and use of blood transfusions, the need to use hemostatic agents (66.7% and 43.8%, $p = 0.04$) as well as the need to use stitches during parenchymal transection phases (52.4% and 8.3%, $p = 0.003$) were significantly higher in the Pure Robotic compared with the Robo-Lap group, as reported in **Table 2**. Four cases in the Pure Robotic and 29 in the Robo-Lap groups also performed a second liver resection during the same day in the theatre.

Postoperative morbidity was similar (more specifically, there were no differences in the incidence of hemorrhage), as well as mortality and length of postoperative stay.

Achievement of Textbook Outcomes (Secondary Endpoint)

TO were achieved in a significantly lower proportion of patients in the Pure Robotic (4 patients, 19%) compared with the Robo-Lap group (25 patients, 52.1%) with $p = 0.026$. **Figure 2** reports the rate of achievement of every item included in the definition of TO according to treatment group.

DISCUSSION

The results of this study show how—in the setting of major anatomical liver resections—the Robo-Lap approach maximizes the performance of surgery by reducing the incidence of intraoperative complications and time for liver transection compared to the pure robotic technique, allowing to optimize operating room time and increasing the chances of obtaining ideal intraoperative outcomes (hence achieving the TO). In an era where the robotic approach is experiencing a widespread diffusion in the field of minimally invasive liver disease, this issue is being addressed, to the best of our knowledge, for the first time since the Robo-Lap technique was described.

Table 1.
Patients and Disease Characteristics According to Treatment Group

	Pure Robotic Group (n = 21)	Robo-Lap Group (n = 48)	*p*
Age (years) (Mean ± SD)	66 ± 5	63 ± 8	0.712
Male sex, n (%)	13 (61.9)	23 (47.9)	0.534
ASA score, n (%)*			0.198
1	2 (9.5)	3 (6.3)	
2	13 (61.9)	29 (60.4)	
3	6 (28.6)	16 (33.3)	
BMI (Mean ± SD)	23.5 ± 2.3	24.1 ± 2.4	0.582
Underlying liver disease, n (%)			0.522
None	4 (19)	7 (14.6)	
Steatosis/mild impairment	14 (66.7)	35 (72.9)	
Cirrhosis	3 (14.3)	6 (12.5)	
Previous abdominal surgery, n (%)*	5 (23.8)	13 (27.1)	0.188
Previous liver surgery, n (%)	1 (4.8)	3 (6.3)	
Previous interventional procedures, n (%)*			0.004
Portal vein embolization	1 (4.8)	2 (4.2)	
Hepatic deprivation	4 (19)	13 (27.1)	
Biliary drainage	3 (14.3)	16 (33.3)	
Indication, n (%)*			0.527
Malignant	19 (90.5)	44 (91.7)	
Colorectal Cancer Metastases	6 (28.6)	10 (20.8)	
Noncolorectal Cancer Metastases	0	1 (2.1)	
Hepatocellular Carcinoma	8 (38.1)	10 (20.8)	
Cholangiocarcinoma	5 (23.8)	23 (47.9)	
Benign	2 (9.5)	4 (8.3)	
Adenoma	1 (4.8)	1 (2.1)	
Hemangioma	1 (4.8)	2 (4.2)	
Hepatolitiasis	0	1 (2.1)	
Size (cm)* (Mean ± SD)	6.9 ± 3.6	6.5 ± 3.3	0.248
Tumor number, n (%)			0.902
Single	13 (61.9)	36 (75)	
Multiple	8 (38.1)	12 (25)	
Type of hepatectomy, n (%)			0.956
Right hepatectomy	11 (52.4)	28 (58.3)	
Left hepatectomy	10 (47.6)	20 (41.7)	
Associated procedures, n (%)*	8 (38.1)	27 (56.3)	0.055
Colorectal resection	2 (9.5)	4 (8.3)	
Lymphadenectomy	5 (23.8)	23 (47.9)	
Biliary anastomosis	3 (14.3)	17 (35.4)	
Others	1 (4.8)	2 (4.2)	

ASA, America Society of Anesthesiologists; BMI, body mass index; SD, standard deviation.
*Clavien-Dindo Classification.

Table 2.
Intraoperative and Postoperative Details

	Pure Robotic (n = 21)	Robo-Lap (n = 48)	*p*
Pringle Maneuver, n (%)			0.456
Not performed	1 (4.8)	1 (2.1)	
Performed	20 (95.2)	47 (97.9)	
Length of surgery (min), Median (range)	390 ± 80	370 ± 105	0.241
Length of parenchymal transection (min), Median (range)	240 ± 60	180 ± 65	0.03
Blood Loss (mL), Median (range)	450 ± 250	350 ± 150	0.344
Surgical margin, n (%)			0.711
R0	20 (95.2)	44 (91.7)	
R1	1 (4.8)	4 (8.3)	
Intraoperative complications, n (%)	18 (85.7)	19 (39.6)	< 0.001
Intraoperative complications according to Satava, n (%)			
Grade I	12 (57.1)	10 (20.8)	
Grade II	5 (23.8)	7 (14.6)	
Grade III	1 (4.8)	2 (4.2)	
Conversion, n (%)	2 (9.5)	5 (10.4)	0.489
Surgical margin (mm) (Mean ± SD)	10 ± 5	9 ± 7	0.289
Intraoperative blood transfusions, n (%)			0.529
No	18 (85.7)	40 (83.3)	
Yes	3 (14.3)	8 (16.7)	
Overall blood transfusions, n (%)			0.109
No	15 (71.4)	30 (62.5)	
Yes	6 (28.6)	18 (37.5)	
Need for hemostatic, n (%)	14 (66.7)	21 (43.8)	0.047
Need for stitches during parenchymal transection, n (%)	11 (52.4)	4 (8.3)	0.003
Feasibility of a second liver resection in the same day, n (%)	4 (19)	29 (60.4)	0.026
Achievement of intraoperative textbook outcomes, n (%)	4 (19)	25 (52.1)	
Complications, n (%)			0.289
Hemorrhage	2 (9.5)	3 (6.3)	
Wound infection	0	1 (2.1)	
Biliary fistula	3 (14.3)	4 (8.3)	
Abdominal collection	1 (4.8)	3 (6.3)	
Transient liver failure	3 (14.3)	7 (14.6)	
Pulmonary embolism	1 (4.8)	2 (4.2)	
Pleural effusion	4 (19)	9 (18.8)	
Pneumonia	2 (9.5)	3 (6.3)	
Atrial fibrillation	1 (4.8)	2 (4.2)	
Fever	2 (9.5)	5 (10.4)	

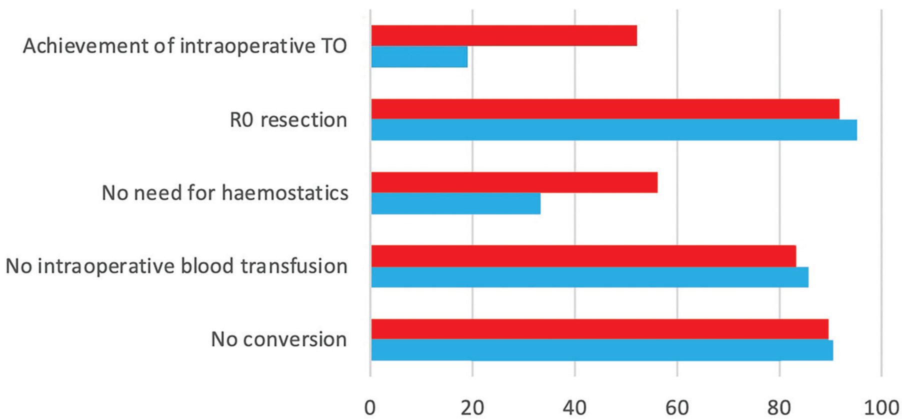
Table 2. Continued

	Pure Robotic (n = 21)	Robo-Lap (n = 48)	*p*
Morbidity, n (%)	8 (38.1)	22 (45.8)	0.057
Grade of complications, n (%)*			
Minor			
I grade	0	1 (2.1)	0.178
II grade	5 (23.8)	16 (33.3)	
Major			
IIIa grade	2 (9.5)	4 (8.3)	0.877
IIIb grade	1 (4.8)	1 (2.1)	
Mortality, n (%)	0	1 (2.1)	0.29
Length of stay (days), Median (range)	6 (5 – 21)	6 (4 – 32)	0.57

R0, negative resection margin; R1, positive resection margin.
*Clavien-Dindo Classification.

Further elements of novelty in the present study are the prospective collection of data regarding intraoperative adverse events (to record any deviation from the ideal intraoperative course) and the introduction of the concept of intraoperative TO. The adoption of this study design is aimed at increasing the possibilities of recognizing differences in the outcome of two different transection techniques adopted in the context of minimally invasive robotics.

In the past when comparing parenchymal transection techniques, most studies reported similar outcomes, finally leaving to surgeon's choice the technique to be adopted.[16–19] However, it is possible that the lack of differences among different techniques was a consequence of a low accuracy of the outcomes taken into consideration for the comparison. In the present study, the use of parameters to evaluate the primary endpoint such as intraoperative adverse events, the use of hemostatic



	No conversion	No intraoperative blood transfusion	No need for haemostatics	R0 resection	Achievement of intraoperative TO
Robo-Lap	89,6	83,3	56,2	91,7	52,1
Pure Robotic	90,5	85,7	33,3	95,2	19

Figure 2. Analysis of intraoperative textbook outcomes according to each factor defining their achievement.

sutures during the parenchymal transection phases and the need of hemostatic on the transection surface is aimed at increasing the specificity and sensitivity of the variables, hence improving the possibility to detect differences.

In particular, the decision to use the Satava classification to analyze grade I complications (intraoperative incidents managed without changes in the surgical approach and without consequences for the patient) and grade II complications (incidents with consequences for the patient including increased blood loss and use of sutures for vascular damage, etc.)[16] was aimed at increasing the possibility of recognizing differences in the intraoperative course of procedures constituting a deviation from the ideal course but not always leading to conversion.

In fact, conversion represents the epiphenomenon of an intraoperative complication that cannot be managed by minimally invasive methods;[21–23] however, most intraoperative events do not compromise the minimally invasive feasibility of the operation and in this perspective the analysis of intraoperative complications according to Satava has great clinical significance. In the Robo-Lap approach, in fact, a significantly lower incidence of minor complications is recorded, which are not the cause of conversion, but which influence intraoperative management. It is possible—although not yet described in the literature—that, just as conversion significantly influences the risk of intraoperative morbidity and mortality, in the same way any intraoperative event has a perioperative weight.

A more favorable intraoperative outcome determined by the Robo-Lap approach is also evident from a reduced need to use hemostatic sutures to correct damages to portal or hepatic branches and from a reduced need to use hemostatic for temporary or definitive hemostasis. It is likely that liver parenchymal dissection conducted with bipolar forceps lacks accuracy since tips of the instruments may inadvertently cause vascular damage. The dexterity of the robotic platform allows an easier correction of these damages compared to laparoscopy (it is in fact easier to perform sutures even on fragile vessels such as the hepatic ones) and consequently conversion is avoided. It is in fact reported in a large multi-institutional series that the robotic approach can reduce the risk of conversion in more complex operations when compared with laparoscopic approach.

A more favorable intraoperative trend is also evident from the analysis of the parenchymal transection times which are significantly reduced in the Robo-Lap approach and which therefore allows in many cases the ability perform a second liver resection on the same day of the analyzed procedure, thus optimizing the management of operating room resources. Overall, patients who do not require biliary-enteric anastomoses or any other time-consuming associated procedures allow access to the operating room for a second liver surgery during the same day. In the present series no difference in the overall surgical times is detected between the two groups since length of surgery in the Robo-Lap Approach is impacted by a higher representation of perihilar cholangiocarcinomas. In these patients, the time required for the biliary-digestive anastomosis lengthens the overall procedure time.

The concept of intraoperative TO was introduced to evaluate the probability of an "ideal" intraoperative conduction, using a composite qualitative measure that includes multiple endpoints chosen as representative of an intraoperative course without complications. The choice of the parameters to be included in the definition of intraoperative TO was made specifically for this study since it has not yet been defined in the literature (only postoperative TO in liver surgery have been described), potentially a limitation of this analysis. Other limitations are represented by the still relatively small sample being analyzed and restricted to a specific group of procedures. It is possible that in parallel with the increase in sample size, a net benefit in the postoperative outcome in terms of reduction of morbidity and transfusion risk will be recorded in patients showing favorable intraoperative results.

The benefits described for the Robo-Lap approach are currently limited to major hepatectomies. The decision to restrict the analysis to this specific groups of patients was taken to obtain a homogeneous sample of procedures in terms of characteristics of the transection phase. It will be necessary to evaluate the impact of the Robo-Lap approach in complex resections (according to the definition given by the complexity scores). It is also possible that these results are influenced by the extensive expertise of the group with the use of the ultrasonic dissector, both in open and minimally invasive surgery. This attitude potentially negatively influences the performance in the parenchymal transection performed with the mechanic action of the bipolar forceps. Furthermore, it is possible that in the presence of a fibrotic or cirrhotic parenchyma where the ultrasonic dissector has a less effective action, the results may be less markedly in favor of the Robo-Lap approach.

CONCLUSIONS

In conclusion, the data of the present study suggest a favorable role of the Robo-Lap approach in robotic major resections as it allows an improvement of the intraoperative results, a greater probability of an uneventful conduction (i.e. reaching the TO) of the procedure and therefore a better management of operating room time and of resources allocation.

References

1. Ratti F, Cipriani F, Ingallinella S, Tudisco A, Catena M, Aldrighetti L. Robotic approach for lymphadenectomy in biliary tumours: the missing ring between the benefits of laparoscopic and reproducibility of open approach? *Ann Surg*. 2022; online ahead of print.

2. Cucchetti A, et al. Variations in risk-adjusted outcomes following 4318 laparoscopic liver resections. *J Hepatobiliary Pancreat Sci*. 2022;29(5):521–530.

3. Ratti F, Fiorentini G, Cipriani F, Catena M, Paganelli M, Aldrighetti L. Laparoscopic vs open surgery for colorectal liver metastases. *JAMA Surg*. 2018;153(11):1028–1035.

4. Fretland ÅA, et al. Laparoscopic versus open resection for colorectal liver metastases: The OSLO-COMET Randomized Controlled Trial. *Ann Surg*. 2018;267(2):199–207.

5. Cipriani F, Ratti F, Aldrighetti L. Laparoscopic liver resections at the gates of 2020: a stand-alone field of hepatobiliary surgery. *Hepatobiliary Surg Nutr*. 2020;9(3):371–373.

6. Cipriani F, et al. Pure laparoscopic versus robotic liver resections: multicentric propensity score-based analysis with stratification according to difficulty scores. *J Hepatobiliary Pancreat Sci*. 2022;29(10):1108–1123.

7. Ratti F, Cipriani F, Fiorentini G, Catena M, Paganelli M, Aldrighetti L. Have we really understood when the efforts of laparoscopic liver resection are justified?-a complexity-based appraisal of the differential benefit. *Hepatobiliary Surg Nutr*. 2022;11(3):363–374.

8. Fiorentini G, Ratti F, Aldrighetti L. The LiTOS-approach: liver partitioning and total venous occlusion for staged hepatectomy. *J Gastrointest Surg*. 2022;26(10):2244–2247.

9. Zwart MJW, et al. Pan-European survey on the implementation of robotic and laparoscopic minimally invasive liver surgery. *HPB (Oxford)*. 2022;24(3):322–331.

10. Aldrighetti L, Catena M, Ratti F. Maximizing performance in complex minimally invasive surgery of the liver: the Robo-Lap approach. *J Gastrointest Surg*. 2022;26(8):1811–1813.

11. Nagino M, et al. Proposal of a new comprehensive notation for hepatectomy: the "New World" terminology. *Ann Surg*. 2021;274(1):1–3.

12. Chua D, Syn N, Koh YX, Goh BKP. Learning curves in minimally invasive hepatectomy: systematic review and meta-regression analysis. *Br J Surg*. 2021;108(4):351–358.

13. Görgec B, et al. Assessment of textbook outcome in laparoscopic and open liver surgery. *JAMA Surg*. 2021;156(8):e212064.

14. Tsilimigras DI, Pawlik TM, Moris D. Textbook outcomes in hepatobiliary and pancreatic surgery. *World J Gastroenterol*. 2021;27(15):1524–1530.

15. Clavien PA, et al. The Clavien-Dindo classification of surgical complications: five-year experience. *Ann Surg*. 2009; 250(2):187–196.

16. Kazaryan AM, Røsok BI, Edwin B. Morbidity assessment in surgery: refinement proposal based on a concept of perioperative adverse events. *ISRN Surg*. 2013;2013:625093.

17. Reddy SK, Tsung A, Geller DA. Laparoscopic liver resection. *World J Surg*. 2011;35(7):1478–1486.

18. Aldrighetti L, et al. Ultrasonic-mediated laparoscopic liver transection. *Am J Surg*. 2008;195(2):270–272.

19. Wakabayashi G, et al. Recommendations for laparoscopic liver resection: a report from the second international consensus conference held in Morioka. *Ann Surg*. 2015;261(4):619–629.

20. Serenari M, et al Minimally invasive stage 1 to protect against the risk of liver failure: results from the hepatocellular carcinoma series of the associating liver partition and portal vein ligation for staged hepatectomy italian registry. *J Laparoendosc Adv Surg Tech A*. 2020;30(10):1082–1089.

21. Cipriani F, et al Conversion of minimally invasive liver resection for HCC in advanced cirrhosis: clinical impact and role of difficulty scoring systems. *Cancers (Basel)*. 2023;15(5):1432.

22. Cipriani F, Ratti F, Fiorentini G, Catena M, Paganelli M, Aldrighetti L. Pure laparoscopic right hepatectomy: a risk score for conversion for the paradigm of difficult laparoscopic liver resections. A single centre case series. *Int J Surg*. 2020;82:108–115.

23. Halls MC, et al. Conversion for unfavorable intraoperative events results in significantly worse outcomes during laparoscopic liver resection: lessons learned from a multicenter review of 2861 cases. *Ann Surg*. 2018;268(6):1051–1057.